

Effect of Re-Composition Concept Mapping for Sharing Reference Maps on Serial Concept Mapping: A Preliminary Study

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Abstract: In serial concept mapping, a concept map created during one lecture is extended in subsequent lectures, resulting in a comprehensive map over time. The quality of the initial maps directly influences the quality of future maps, making it crucial to enhance the concept maps created in each lecture. Teachers often develop reference concept maps beforehand to evaluate learners' maps and provide feedback based on these reference standards. Incorporating a reference map sharing phase after individual concept mapping is anticipated to improve the quality of learners' maps in each lecture and positively influence subsequent ones. However, the scratch-building method, where learners freely create all components of the map, poses challenges for effective reference map sharing due to discrepancies between the reference and learners' maps. To address this, we explored the re-composition method, where learners construct concept maps by reorganizing pre-provided components, allowing them to concentrate on structural aspects rather than creating the components themselves. This paper compares the effects of reference map sharing between individual concept mapping using the re-composition method and the scratch-building method. In the re-composition method, components are provided by decomposing the reference map, enabling learners to focus on structural differences during the reference map sharing phase. The study was conducted in university lectures, involving three map-building sessions and two reference map sharing sessions across three lectures for both groups. Results showed that the quality of each map (submap) improved incrementally for the re-composition group but not for the scratch-building group. This suggests that reference map sharing in serial concept mapping is more effective when using the re-composition method.

Keywords: concept map, serial concept map, re-composition, prior knowledge, reference map, map quality, knowledge representation, formative assessment

1. Introduction

Concept mapping has been shown to facilitate meaningful learning and create a robust knowledge framework, not only for acquiring new knowledge but also for retaining existing knowledge over extended periods (Novak, 1990). Various methods have emerged from the foundational Novakian concept map, including serial concept mapping, which visualizes the sequential evolution of concepts. According to Campbell (2022), serial concept map develops over multiple iterations leading to the completed concept map, with each iteration involving the provision of materials and the creation of the map. The creation of serial concept maps reflects learners' knowledge growth, a crucial aspect of the learning process (Cañas & Reiska, 2018). This research used two methods for incorporating serial concept mapping: the re-composition method and the scratch building method. The re-composition method involves creating a concept map by re-composing provided concepts and links (Hirashima et al., 2015).

In contrast, the scratch building method is conventional, allowing learners to create their own maps with freedom.

There's no established method to enhance map quality for acquiring new knowledge. In order to tackle the problem, we propose a novel step – the sharing of a reference map. The reference map, constructed by a subject matter expert (lecturer), represents the understanding of the lecturer to convey to learners in preparation for the next lecture. From this activity learners are expected to improve their understanding by reviewing the reference map. The process of sharing a reference map is a form of formative feedback aimed at minimizing the gap between the student's understanding (actual level) and the teacher's understanding (reference level) (William & Thompson, 2008).

In this paper, we experimentally compared the two concept mapping methods: scratch-building and re-composition, in terms of improving map quality with the sharing of a reference map step. We anticipate that the re-composition method will be more effective than the scratch-building method for reviewing the reference map because it requires the learners to build their maps using the same components as the reference map, whereas scratch-building allows learners create their own components. Apart from that, the re-composition method is considered to be high-directed map whereas scratch building method is considered to be low-directed map based on Canas (2023) concept mapping categorization. Low-directed map can lead to meaningless learning because the concepts which students understand may not be accurate or relevant to the topic, thus re-composition method may be better in terms of meaningful learning. The research aims to find an effective way to improve the quality of individual iterations in serial concept mapping, addressing research question below:

RQ: Is re-composition concept mapping more suitable for the sharing of reference map step than scratch-building concept mapping?

H: Re-composition is more suitable for the sharing of reference map step.

2. Literature Review

This section consists of explanations on the theories that supported this research. There are concept map theories including serial concept map, scratch building method and re-composition, and prior knowledge theory

2.1 Concept Map

Novak (2007) describes concept map as being illustrated by connecting lines that link two concepts and are supplemented with linking words or phrases that explain the relationship between them. They are particularly helpful in higher education, where they can be used to identify prior knowledge, present new material, share expert knowledge and understanding, and document knowledge change. Concept map methods are categorized as high-directed and low-directed which impacts how meaningful the learning is (Canas et. al., 2023). In this research, we compare high-directed (re-composition method) and low-directed (scratch building method) for ensuring the map quality.

2.1.1 Serial Concept Map

Serial concept map is a map that evolved in a period of time (Campbell, 2022). For example, the concept map is started on the first week and it will be evolving in the next week iteratively. An N -th iteration concept map is a subset of the $(N + 1)$ -th iteration concept map, demonstrating that the concept map becomes more complex with each iteration.

2.1.2 Scratch Building Method (Low-Directed Map)

The scratch building method is a technique that allows students the freedom to create their own concepts and links, representing a conservative approach to building concept maps without restrictions. While freedom may enhance creativity, Canas (2023) noted that excessive

freedom could result in meaningless learning because the concepts students understand may not be accurate or relevant to the topic.

2.1.3 Re-composition Method (High-Directed Map)

Re-composition is a method of creating a concept map. In this method, learners are provided with concepts and links that can be used to recompose a map based on their understanding (Hirashima et al., 2015). According to previous studies, the re-composition method can help learners achieve meaningful learning and maintain the quality of the concept map (Cañas et al., 2023; Pinandito et al., 2023). However, constructing a map using this method can be challenging and requires considerable effort. The combinations of node-link-node become more complex as the number of provided nodes and links grows. For instance, if ten nodes are provided, there will be 45 possibilities to create a map ($C_{(10, 2)}$). In this research, the concepts and links will be decomposed from the reference map, and the group using the re-composition method need to re-compose them into a concept map.

2.1.4 Formative Assessment on Concept Maps

According to William (2008), formative assessment can be broken down into three process dimensions: the learning state ("Where the learner is right now"), the learning goal ("Where the learner is going"), and the steps to the learning goal ("How to get there"). This research uses the term 'learning state' to refer to the actual level, 'learning goal' to refer to the reference level, and 'gap' to refer to the difference between the actual and reference levels. The process of sharing the reference map represents the steps toward the learning goal or the effort to minimize the gap between the actual and reference levels. Many researchers have suggested that concept maps can be used as a formative assessment tool, including both low-directed and high-directed forms (Blackmann & Friege, 2023; Pailai, 2017).

2.2 Prior Knowledge

Diaz (2017) asserts that prior knowledge plays a fundamental role in the learning process, it serves as a foundation from which individuals can explore new topics, acting as a scaffold for understanding new information, ultimately transforming it into enhanced knowledge. This research defines the first iteration concept map as prior knowledge when creating the second iteration concept map whereas second iteration concept map as prior knowledge when creating the third iteration concept map.

By knowing that the prior knowledge can influence the map quality in the next iteration, so, the researcher tried to incorporate the sharing reference map process to make sure that the prior knowledge can be activated and improve the next iteration map quality.

3. Methodology

This section explains how the research is conducted. The research used experimental methods to compare between 2 groups: (1) group that used scratch building method, (2) group that used re-composition method. The details of the methodology framework will be explained in the next section

3.1 Total Cycle of Iteration and Participants

The research was conducted over three iteration cycles in six Human-Computer Interaction (HCI) classes in Universitas Indonesia. Human-Computer Interaction teaches students about how to build applications from user interaction and user experience perspectives. Universitas Indonesia is ranked first in Indonesia (Quacquarelli Sydmonds Limited, 2024), so the students are based on the top-tier students in Indonesia.

Three classes belonged to the scratch building group (127 students), and three classes belonged to the re-composition group (63 students). The re-composition group was cut in half because there was heavy rain on the data collection day which led to many students being absent. The researcher gave the absent students the opportunity to create their maps on other days until the day before the lecture. However, by the last iteration, only sixty-three students in the re-composition group remained committed to the experiment.

3.2 Shared-Understanding Map Formulation

The reference map is used to share the lecturer's knowledge to the learners, so they can improve their map quality in the next iteration. It is constructed through collaboration between researchers and lecturers to ensure alignment with the learning materials and objectives. It is built iteratively from the first iteration until the last, with evaluations between iterations to check for concepts from students in the scratch building group that are suitable but have not been included in the reference map.

3.3 Concept Map Quality Evaluation

The quality of the map is evaluated based on Mueller's Concept Map Assessment Quality (University of Iowa, n.d.). This evaluation focuses on the legibility, accuracy, completeness, and sophistication of the concept map, aligning with the acquired learning knowledge of the students. Nurmaya (2023) employed this evaluation to evaluate the quality of concept maps concerning higher order thinking skills, thus validating it for other researchers. There are 4 map quality categorizations: exemplary (3), good (2), acceptable (1) and unacceptable (0).

There are three evaluators in each class, who are teaching assistants of HCI classes, to evaluate the concept maps and ensure the validity of the evaluation results. These evaluators are trained alongside the researcher to ensure they share the same understanding of how to evaluate the quality of the concept maps.

3.4 Experimental Procedures

The main activities are delivering the lecture (providing the materials), building the concept map based on the lecture, and sharing the reference map. The sharing process is the new step introduced in this research with both groups after the concept creation phase as mentioned in the introduction section. This step helps students compare their maps with the reference map, allowing them to improve their map quality in the next iteration. The sharing process is beneficial for learners to enhance the map quality in subsequent iterations within serial concept mapping. The activity of this process is explained in the next paragraph.

The lecturer and researcher provided the reference map asynchronously to the students after the concept map creation phase. Additionally, before creating the next iteration's concept map, the lecturer or researcher briefly explained the reference map synchronously. Due to the constraints imposed by the limited time available, learners are not permitted to revise or alter their previously created concept maps from earlier iterations. Instead, they are only allowed to establish connections and relationships with the original, unmodified maps from the preceding iterations, ensuring that each new iteration builds directly upon the initial conceptual foundations without retrospective adjustments.

3.5 Analysis Method

The research found that most of the data are not normally distributed, except for iteration 2 in scratch building method. Therefore, the researcher used the Mann Whitney U test to assess the significant difference of map quality between different group.

4. Result & Discussion

This section explains the results of this research and discusses what can be interpreted from the results regarding map quality comparison to answer the research question.

4.1 Map Quality Comparison on Each Method Group

This result section answers the research question to know which method is more suitable for the sharing reference map process. Upon delving deeper into the components of map quality, Table 1 shows that the re-composition group generally excels in map quality components compared to the scratch building group, except for legibility. In iteration 1, the scratch building group has significantly higher legibility, while the re-composition group scores significantly higher in accuracy, completeness, and sophistication. In iteration 2, legibility remains higher in the scratch building group whereas the re-composition group continues to outperform in accuracy, completeness and sophistication. By iteration 3, legibility differences are no longer significant, but the re-composition group further excels in accuracy, completeness, and sophistication. These results indicate that the re-composition method, coupled with the sharing reference map process, significantly improves map quality over iterations.

Table 1. Map Quality Detailed Components Statistical Analysis with Mann Whitney U Test, SB: Scratch Building, RC: Re-composition

		Average (SB)	Stdev (SB)	Average (RC)	Stdev (RC)	<i>p</i> value	Effect Size (<i>r</i>)
Iteration 1	Legibility	2.62	0.43	2.41	0.37	0.0003	Middle (0.3)
	Accuracy	1.80	0.49	2.04	0.51	0.0000003	Middle (0.4)
	Completeness	1.80	0.50	2.04	0.23	0.001	Small (0.2)
	Sophistication	1.07	0.78	1.65	1.04	0.0001	Middle (0.3)
Iteration 2	Legibility	2.55	0.51	2.33	0.56	0.01	Small (0.2)
	Accuracy	2.02	0.53	2.72	0.36	$5.7E - 16$	Large (0.6)
	Completeness	1.94	0.56	2.41	0.37	$1.7E - 8$	Middle (0.4)
	Sophistication	1.36	0.67	2.49	0.65	$1.5E - 18$	Large (0.6)
Iteration 3	Legibility	2.51	0.52	2.44	0.46	0.20	Small (0.1)
	Accuracy	1.74	0.87	2.89	0.21	$1.2E - 20$	Large (0.7)
	Completeness	2.09	0.48	2.64	0.43	$1.7E - 11$	Large (0.5)
	Sophistication	1.48	0.72	2.68	0.47	$2.2E - 24$	Large (0.7)

Effect sizes of {accuracy, completeness, and sophistication} in Iteration 2 & 3 are higher than Iteration 1, while effect size of {legibility} in Iteration 2 & 3 is lower than Iteration 1. There are differences between Iteration 2 & 3, and Iteration 1 which shows the effect of sharing reference map step. Therefore, these results suggest that the step has more potential to be effective for re-composition condition.

5. Conclusion & Future Works

Based on the results and discussion, this research concludes that re-composition method shows more potential to be effective in sharing reference map process. This is supported by significantly higher detailed components {accuracy, completeness, and sophistication} of map quality compared to the scratch building method with significant differences and higher effect sizes.

Based on the conclusion above, there are future researches that needs to be done in the following.

1. Analyze is there any correlation between the previous iteration map quality and the next iteration map quality.
 - a. Design and conduct another experiment that allows for revisions of previous iteration sub-map before constructing the next iteration sub-map.
2. Conducting additional research focusing on the tighter relationship between concept maps in each iteration.
3. Analyzing the impact on learning outcomes by studying pre and post-tests and the correlation between map quality and test results.

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